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## **SUBSTITUTE SPECIFICATION**

### **TITLE OF THE INVENTION**

Color Image forming apparatus

### **BACKGROUND OF THE INVENTION**

The present invention relates to a color image forming apparatus of the  
5 type which performs printing using a plurality of colors, and, in particular, the  
invention relates to a scanning optical system for use in such an apparatus.

Conventionally, a so-called tandem type color laser beam printer, which is  
constituted by a plurality of scanning optical systems and a plurality of electro-  
photographic units, has been known. Latent images, for example, for cyan,  
10 magenta, yellow and black, which correspond to respective primary colors, are  
produced by the scanning optical systems on respective charged photosensitive  
drums. A toner image which is obtained by developing the latent images using a  
developing unit is transferred on paper transported by a transport belt, and,  
thereafter, the toner image is fixed by a fixing unit to form a color image.

15 The typical tandem type color laser beam printer requires four scanning  
optical systems. If the number of scanning optical systems can be reduced, a  
great advantage involving a cost reduction of the apparatus is can be obtained.  
In particular, the number of polygon scanner motors can be reduced, and, in  
addition to such cost reduction, the electric power consumption of the apparatus  
20 also can be reduced.

Therefore, measures for reducing the number of polygon scanner motors  
have been proposed. For example, JP-A-3-42612 discloses a technique in  
which, in a tandem type color laser beam printer using four photosensitive  
drums, a single polygon scanner motor is provided, and by irradiating laser  
25 beams from both right and left directions of the polygon scanner, four laser  
beams are scanned at the same time by different mirror surfaces.

However, in the apparatus disclosed in JP-A-3-42612, although a single polygon scanner can be used in common, the corresponding optical systems for the respective laser beams that irradiate onto four photosensitive drums have to be provided independently, so that the overall size of the optical systems can not be fully reduced.

For this reason, JP-A-6-286226 proposes a color image forming apparatus of reduced size and cost, in which the optical parts which irradiate a plurality of laser beams on a plurality of photosensitive drums are used in common.

The disclosed color image forming apparatus is constituted by a semiconductor laser array which emits four laser beams, a polygon mirror which reflects and deflects in common the four laser beams emitted from the semiconductor array, reflection mirrors which guide the four beams that have been reflected and deflected by the polygon mirror in predetermined directions, an f- $\theta$  lens which operates to focus the four laser beams reflected by the reflection mirrors in the main scanning direction and to scan the beams at an equal speed on exposure lines on the photosensitive drums, a prism type reflection mirror which splits the four laser beams that have passed through the f- $\theta$  lens in directions depending on the arrangement locations of the photosensitive drums, further reflection mirrors which respectively guide the four laser beams that have been split by the prism type reflection mirror in the corresponding photosensitive drums, and cylindrical lenses which respectively focus the four laser beams reflected by the reflection mirrors to the sub-scanning direction.

In the above-described structure, when the four laser beams, which are modulated depending on the image data of cyan (C), magenta (M), yellow (Y) and black (B), are emitted from the semiconductor laser array, the laser beams are reflected and deflected in common at the polygon mirror and make incidence

to the prism type reflection mirror via the reflection mirrors and the f- $\theta$  lens and wherein the laser beams are split in directions depending on the arrangement positions of the respective photosensitive drums. The split four laser beams are respectively reflected by the reflection mirrors, which guide the same to the  
5 respective corresponding photosensitive drums, expose the rotating photosensitive drums that have been charged in advance via the cylindrical lenses and form electrostatic latent images on the surface of the photosensitive drums.

As another embodiment thereof, a semiconductor laser array, which  
10 operates to emit eight laser beams arranged longitudinally is used, the eight laser beams are transmitted in a bundle, respective optical paths are split for every group, each having two laser beams, by a beam splitting means, and an interlaced scanning by two lines longitudinally on the respective photosensitive drums is carried out. Further, in further embodiments, a multi-beam  
15 semiconductor laser array having different element intervals is used; and, through provision of a micro lens array between the multi-beam semiconductor laser array and a collimator, a continued scanning on the respective photosensitive drums is performed instead of the interlaced scanning.

However, with such a color image forming apparatus, when the number of  
20 laser beams is increased in dependence on high speed demand, the laser beams at both ends of the semiconductor laser array in which the laser beams are arranged longitudinally may extend beyond the image circle of the lens and cause aberration, which makes it difficult to obtain a predetermined optical performance.

25 Further, a possible improvement of the above-described problem may make the lens structure more complex, which makes a size reduction of the optical unit difficult and increases the cost thereof.

Alternatively, when an improvement is attempted by narrowing the interval of the elements, the laser beam splitting onto the respective photosensitive drums is made difficult, and an inconvenience involving a variation in the laser optical output is caused because of droops due to the self heat generation of the laser elements and cross talk due to heat generation by the adjacent laser elements. When the micro lens array is provided between the semiconductor laser array and the collimator, the number of parts and the adjusting steps increase and a problem which is likely affected by an imaging position deviation due to thermal deformation depending on the attachment thereof is caused.

#### SUMMARY OF THE INVENTION

An object of the present invention is to provide a color image forming apparatus in which the conventional drawbacks as described above are eliminated, so as to provide a high speed apparatus which is small in size and low in cost.

The present invention, which achieves the above-stated object, is directed to a color image forming apparatus in which, on  $n(n \geq 2)$  photosensitive drums corresponding to respective colors ( for example, cyan, magenta, yellow and black ), respective latent images are formed by irradiation of laser beams.

A first aspect of the present invention is exemplified by a semiconductor laser array in which  $m(m \geq 2)$  laser beam emitting points are arranged in the row direction thereof and  $n$  in the line direction thereof corresponding to the number of the photosensitive drums, beam splitting means, for example, such as a cylindrical lens which splits the respective laser beams for every line on the semiconductor laser array so that  $m$  laser beams emitted from one of the rows on the semiconductor laser array scan the same photosensitive drum, and beam deflection means, for example, such as a polygon mirror which deflects in common  $n$  laser beams for every line emitted from the semiconductor laser array

and irradiates the same onto the respective photosensitive drums, wherein, the arrangement direction of  $m$  beam spots irradiated onto one of the photosensitive drums is inclined by an angle  $\alpha_2$  with respect to the main scanning direction.

A second aspect of the present invention is exemplified by a first  
5 semiconductor laser array and a second semiconductor laser array, each of which has  $m(m \geq 2)$  laser beam emitting points arranged in the row direction thereof and  $n/2$  in line direction thereof, representing half the number of photosensitive drums, a first beam splitting means which splits the respective laser beams for every line on the semiconductor laser array so that  $m$  laser  
10 beams emitted from one of the rows on the first semiconductor laser array scan the same photosensitive drum, a second beam splitting means which splits the respective laser beams for every line on the semiconductor laser array so that  $m$  laser beams emitted from one of the rows on the second semiconductor laser array scan the same photosensitive drum, and beam deflection means which  
15 deflects at different faces thereof  $n$  laser beams for every line emitted from the first semiconductor laser array and the second semiconductor laser array and irradiates the same onto the respective photosensitive drums, wherein, the arrangement direction of  $m$  beam spots irradiated onto one of the photosensitive drums is inclined by an angle  $\alpha_2$  with respect to the main scanning direction.

20 A third aspect of the present invention is exemplified by a semiconductor laser array in which  $m(m \geq 2)$  laser beam emitting points are arranged in the row direction thereof and  $n/2$  in line direction thereof, representing half the number of photosensitive drums, a beam splitting means which splits the respective laser beams for every line on the semiconductor laser array so that  $m$  laser beams  
25 emitted from one of the rows on the semiconductor laser array scan the same photosensitive drum and beam deflection means which deflects in common  $n/2$  laser beams for every line emitted from the semiconductor laser array and irradiates the same onto the respective photosensitive drums, wherein, the

arrangement direction of m beam spots irradiated onto one of the photosensitive drums is inclined by an angle  $\alpha_2$  with respect to the main scanning direction.

A fourth aspect of the present invention is characterized in that, in any of the first through third aspects of the invention, by inclining the semiconductor laser array as a whole by an angle  $\alpha_1$ , the arrangement direction of m beam spots irradiated on the photosensitive drums is inclined by the angle  $\alpha_2$  ( $\alpha_1 = \alpha_2$ ) with respect to the main scanning direction.

A fifth aspect of the present invention is characterized in that, in any of the first through third aspects of the invention, by inclining the alignment in the row direction of the light emitting points with respect to the alignment in the line direction by an angle  $(90^\circ - \alpha_3)$ , the arrangement direction of m beam spots irradiated on the photosensitive drums is inclined by the angle  $\alpha_2$  ( $90^\circ - \alpha_3 = \alpha_2$ ) with respect to the main scanning direction.

## BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic diagram of a color image forming apparatus representing a first embodiment of the present invention as seen from the main scanning direction;

Fig. 2 is a diagram showing beam loci as seen from the sub-scanning direction before a polygon mirror in the color image forming apparatus;

Fig. 3 is a diagram showing beam loci as seen from the sub-scanning direction after a polygon mirror in the color image forming apparatus;

Figs. 4(a) and 4(b) are diagrams showing the arrangement of light sources on a semiconductor laser array used for the color image forming apparatus;

Fig. 5 is a diagram showing an arrangement of beam spots on a photosensitive drum in the color image forming apparatus;

Fig. 6 is a diagram showing a relationship between an arrangement of light sources on a semiconductor laser array and beam spots on a photosensitive drum;

Fig. 7 is a plane view of a semiconductor laser array representing a first  
5 modification of the present invention;

Fig. 8 is a plane view of a semiconductor laser array representing a second modification of the present invention;

Fig. 9 is a diagram showing beam loci as seen from the sub-scanning direction after a polygon mirror in a color image forming apparatus representing  
10 a second embodiment of the present invention;

Fig. 10 is a diagram showing beam loci as seen from the sub-scanning direction after a polygon mirror in a color image forming apparatus representing a third embodiment of the present invention;

Fig. 11 is a diagram showing beam loci as seen from the sub-scanning direction after a polygon mirror in a color image forming apparatus representing  
15 a fourth embodiment of the present invention; and

Fig. 12 is a diagrammatic perspective view of a color image forming apparatus representing a fifth embodiment of the present invention.

## 20 DETAILED DESCRIPTION OF THE EMBODIMENTS

Fig. 1 is a schematic diagram of a color image forming apparatus representing a first embodiment of the present invention as seen from the main scanning direction, which color image forming apparatus is a tandem type color laser printer.

25 In the drawing, numeral 1 denotes a semiconductor laser array, which includes 12 light sources (light emitting points) 1-1 ~ 1-12 in total, arranged in a two dimensional array of 3 light sources (in row direction) by 4 light sources (in line direction) as shown, for example, in Fig. 4(a); and, from these light sources,

12 laser beams are emitted. In the present embodiment, although light sources in a 3 x 4 array are illustrated, any semiconductor laser array having light sources in an  $m \times n$  ( $m \geq 2, n \geq 2$ ) array can be used.

Fig. 1 shows the loci of the beams emitted from the light sources 1-1, 1-2 and 1-3 for facilitating an understanding of the invention. The laser beams B1, B2 and B3, which are emitted from the light sources 1-1, 1-2 and 1-3, are collimated by a collimator-lens 2, and the respective laser beams are irradiated on a polygon mirror 6 via cylindrical lenses 4 and 5.

The laser beams reflected by the polygon mirror 6 scan the circumferential surface of a photosensitive drum 9-1 via an F- $\theta$  lens 7 and a cylindrical lens 8-1. For example, a photosensitive belt can be used in place of the photosensitive drum. The direction scanned by the polygon mirror 6 is defined as main scanning direction, and a direction perpendicular to the main scanning direction, namely the moving direction (rotating direction) of the photosensitive drum 9-1, is defined as a sub-scanning direction.

The cylindrical lenses 4 and 5 are used for bringing the laser beams B1, B2 and B3 close to each other on the mirror face of the polygon mirror 6 with regard to the scanning direction, whereby the effective scan width on the mirror face of the polygon mirror 6 can be small. The F- $\theta$  lens 7 functions so that, through rotation of the polygon mirror 6, the beams scan on the photosensitive drum 9-1 with an equal speed.

Fig. 2 shows the beam loci from the semiconductor laser array 1 in the line direction to the polygon mirror 6. The beams B2, B5, B8 and B11 that are emitted from the light sources 1-2, 1-5, 1-8 and 1-11 and are arranged in the line direction on the semiconductor laser array 1 are collimated by the collimator lens 2, split respectively by the cylindrical lens 3 and imaged on the polygon mirror 6.

Herein, when assuming that the distance from the center point between the light sources 1-2 and 1-11 to the light source 1-2 is  $d$ , and the lens optical



axis passes through the center point; and, further assuming that the imaging position of the beam B2 on the polygon mirror 6 is BS2, the focal distances of the collimator lens 2 and the cylindrical lens 3 are respectively F1 and F2, and the angle formed by the beam collimated by the collimator lens 2 with respect to the optical axis is  $\theta_1$ , where  $\theta_1$  is defined by a function  $\theta_1=f(F1,d,F2)$ , and the beam irradiated onto the polygon mirror 6 is made incident at an angle  $\theta=180^\circ-(\theta_1+90^\circ)$  with respect to the mirror face.

In the drawing, only the angle with respect to the light source 1-2 is shown, however, with respect to the beams emitted from the other light sources, a similar relationship stands. In the present embodiment, although the cylindrical lens 3 is shown as being disposed at the position of the focal distance F1 of the collimator lens 2, the cylindrical lens 3 need not necessarily be disposed at that position.

Fig. 3 shows the loci in the sub-scanning direction of the beams reflected from the polygon mirror 6. The respective beams B1 ~ B12 that are reflected from the polygon mirror 6 are reflected at different angles. In this regard, the beams B1 ~ B3 are reflected at substantially the same angle  $\theta$  (same as the incidence angle  $\theta$  shown in Fig. 2), and, in a like manner, the groups of the respective beams B4 ~ B6, B7 ~ B9 and B10 ~ 12 are respectively reflected at different angles.

The respective beams B1 ~ B12 are imaged via the F- $\theta$  lens 7 and respective cylindrical lenses 8-1 ~ 8-4 on the respective photosensitive drums 9-1 ~ 9-4 and scan the same. The respective photosensitive drums 9-1 ~ 9-4 are arranged at an equal distance along a transport direction A of print media, such as paper sheets, and an intermediate image transfer body, serving as a recording medium. In the present embodiment, the photosensitive drum 9-1 is used for black (BK), the photosensitive drum 9-2 is used for yellow (Y), the

photosensitive drum 9-3 is used for magenta (M) and the photosensitive drum 9-4 is used for cyan (C); and, they are designed to rotate in a clockwise direction.

On each of the respective photosensitive drums 9-1 ~ 9-4, three beams are respectively imaged and scan the same. Fig. 5 shows the disposition of the beam spots on one of the photosensitive drums 9. In the drawing, the beam spots BS1 ~ BS3 of the beams B1 ~ B3 on the photosensitive drum 9-1 are shown. As shown in the drawing, the direction of the beam spots BS1 ~ BS3 is aligned at an angle of  $\alpha_2$  with respect to the main scanning direction; and, when assuming that the printing density is 600DPI, the scanning interval of the beam spots is 42.3 $\mu$ m. The inclination  $\alpha_2$  can be realized by inclining the semiconductor laser array 1 as a whole by an angle of  $\alpha_1$  ( $\alpha_1=\alpha_2$ ). In the present embodiment, the angle  $\alpha_1$  ( $=\alpha_2$ ) is 19.47°.

Fig. 6 is a diagram showing a relationship between the arrangement of the respective light sources 1-1 ~ 1-12 on the semiconductor laser array 1 and the beam spots BS1 ~ BS12 on the photosensitive drums 9-1 ~ 9-4.

In the present embodiment, as shown in the drawing, twelve light sources 1-1 ~ 1-12 in total are arranged at an equal interval, with three in the row direction (X direction) and four in the line direction (Y direction), which corresponds to the number of photosensitive drums 9-1 ~ 9-4.

The beams B1 ~ B3, which are arranged on the first row and are emitted from the light sources 1-1 ~ 1-3, are irradiated onto the photosensitive drum 9-1 and form the beam spots BS1 ~ BS3. Similarly, by irradiation of the light sources 1-4 ~ 1-6 on the second row, the beam spots BS4 ~ BS6 are formed on the photosensitive drum 9-2, by irradiation of the light sources 1-7 ~ 1-9 on the third row, the beam spots BS7 ~ BS9 are formed on the photosensitive drum 9-3, and by irradiation of the light sources 1-10 ~ 1-12 on the fourth row, the beam spots BS10 ~ BS12 are formed on the photosensitive drum 9-4.

In order that the three laser beams emitted from one row on the semiconductor laser array 1 will scan the same photosensitive drum 9, the cylindrical lenses 4 and 5 are used, which serve as a beam splitting means for splitting the respective laser beams for every row on the semiconductor laser array 1.

The polygon mirror 6 serves as a beam deflecting means for deflecting in common the beams B1, B4, B7 and B10 emitted from the light sources 1-1, 1-4, 1-7 and 1-10 that are arranged on the first line and for irradiating the same onto the respective photosensitive drums 9-1, ~ 9-4.

A proper interval L between the light sources (light emitting points) on the semiconductor laser array 1 is more than  $50\mu\text{m}$ . If the interval is less than  $50\mu\text{m}$ , the beam splitting becomes difficult, and, at the same time, problems, such as cross talk between the light sources(light emitting points), are caused.

Fig. 7 is a diagram showing a first modification of the semiconductor laser array 1. The main difference between the present modification from the embodiment as shown in connection with Fig. 4(b) is that the alignment in the row direction (X direction) of the light sources 1-1 ~ 1-12 is, in advance, inclined by an angle of  $(90^\circ - \alpha_3)$  with respect to the alignment in the line direction (Y direction). As a result, the arrangement direction of the three beam spots irradiated on the photosensitive drum 9 is inclined by an angle of  $\alpha_2 (= 90^\circ - \alpha_3)$  with respect to the main scanning direction. Accordingly, with the present modification, it is unnecessary to incline the semiconductor laser array 1 as a whole by the angle  $\alpha_1$ , as shown in Fig. 4(b).

Fig. 8 is a diagram showing a second modification of the semiconductor laser array 1. The main difference between the present modification from the embodiment as shown in Fig. 4(b) is that the number of light sources 1-1 ~ 1-12 is determined to be half ( $n/2$ ) the number of photosensitive drums, namely two for every line and the interval between the lines is determined as  $L/2$ .

Now, an image distortion caused when the laser beams make incidence in an inclined manner with respect the optical axis of the F- $\theta$  lens 7 will be discussed.

In the scanning lines that are scanned by the laser beams making incidence in an inclined manner with respect to the optical axis of the F- $\theta$  lens 7, an arcuate bent can be caused on the imaging face, namely, on the photosensitive drum 9, due to distorted aberration. The phenomenon, which causes the bent in the scanning lines, is a significant problem for a multi-beam laser printer in which a photosensitive drum is inclusively scanned by a plurality of laser beams. The above-stated problem can be resolved when individually divided F- $\theta$  lenses are disposed so as to be substantially perpendicular with respect to the ray directions of the respective beams. Namely, through the provision of four F- $\theta$  lenses 7-1 ~ 7-4, as shown in Fig. 9, the bent character of the scanning lines can be suppressed (second embodiment).

In Figs. 10 and 11, which relate to third and fourth embodiments, reflection mirrors 10-1 ~ 10-7 are provided between the respective F- $\theta$  lenses 7-1 ~ 7-4 and the respective cylindrical lenses 8-1 ~ 8-4, whereby the arrangement relation between the photosensitive drums 9-1 ~ 9-4 is modified. The number and the position of the reflection mirrors for the respective beams are determined so that the lengths of the optical paths of the respective beams are the same.

In the above-described embodiments, an example of four photosensitive drums and a light source arrangement consisting of a  $4 \times m$  ( $m \geq 2$ ) light source array was described, however, the two dimensional beam arrangement has to be modified depending on the number of photosensitive drums. Namely, when assuming that the number of photosensitive drums is  $n$ , the light source arrangement on a semiconductor laser array is determined to be  $n \times m$  ( $n \geq 2, m \geq 2$ ).

Fig. 12 is a diagram showing a fifth embodiment in which two semiconductor laser arrays are used. Namely, the two semiconductor laser arrays are constituted by a first semiconductor laser array 1a and a second semiconductor laser array 1b, in each of which two light sources are respectively arranged both in the row and line directions. The semiconductor laser arrays 1a and 1b are inclined by an angle of  $\alpha_1$  in a manner similar to that shown in Fig. 4(b).

The laser beams B1 ~ B4, which are emitted from the light sources 1-1 ~ 1-4 on the first semiconductor laser array 1a, are irradiated on a first reflection face 11a of the polygon mirror 6 via the first collimator lens 2a and the first cylindrical lenses 3a, 4a and 5a. The laser beams B1, B2 and B3, B4 are split by the first cylindrical lenses 4a and 5a, deflected in common by the first reflection face 11a of the polygon mirror 6 and led to the sides of the photosensitive drums 9-1 and 9-2 (not shown).

The laser beams B5 ~ B8, which are emitted from the light sources 1-5 ~ 1-8 on the second semiconductor laser array 1b, are irradiated on a second reflection face 11b, which is different from the first reflection face 11a, of the polygon mirror 6 via the second collimator lens 2b and the second cylindrical lenses 3b, 4b and 5b. The laser beams B5, B6 and B7, B8 are split by the second cylindrical lenses 4b and 5b, deflected in common by the second reflection face 11b of the polygon mirror 6 and led to the sides of the photosensitive drums 9-3 and 9-4 (not shown).

In the above-described embodiments, in order that m laser beams emitted from one row on the semiconductor laser array scan the same photosensitive drum, cylindrical lenses are used, which serve as a beam splitting means for splitting the respective laser beams for every row on the semiconductor laser array, however, other beam splitting means, such as a prism, can be used in place of the cylindrical lenses.

When the above-described multi beam semiconductor laser arrays are employed in a tandem type laser beam printer or a one-path multi-color type laser beam printer, a small size, low cost and low power consumption laser beam printer having a high printing speed and a highly fine saturation can be realized.

According to the present invention, the optical system in a color image forming apparatus can be used in common, thereby, the size and cost of the apparatus can be achieved. Further, the beam deflection means in the apparatus also can be used in common, thereby, a reduction in the power consumption of the apparatus can be reduced.